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A 3D Modeling Perspective: The Juxtaposition between Nature and Technology

Caroline Grace Brustowicz
Union College - Schenectady, NY

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By

Caroline Grace Brustowicz

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Abstract

For my senior thesis I explore the juxtaposition between nature and technology. There is beauty in the ubiquitous contrast and coexistence between these two entities, which we encounter on a daily basis. My work has been inspired by Ernst Haeckel, a German biologist, naturalist, and artist from the early 1900's. His artwork includes over 100 detailed drawings, prints, and multi-colored illustrations of animals and sea creatures with a focus on representing the intricate details found in nature. I've emulated this attention to detail within nature by modeling (using Cinema 4D software and 3D printing with a MakerBot printer) sculptures that embody the interaction between nature in a molecular form, while using the capabilities of industrialized technology. I have extended the process employed by Haeckel by visually exploring the new 3D printing medium in more detailed and complex ways. Light is incorporated within my sculptures to abstractly represent our reliance on the sun. Like the relationship between nature and technology, my showpieces are complex and multi-leveled. To add another nature-based dimension vines are grown and incorporated with some of the 3D printed models themselves. I believe this commingled representation reflects nature and technology in a beautiful and reciprocal relationship.

Part One

The Ideation and Subject Background

I. Ideation

There were many steps to the ideation before arriving at the final 3D printed showpieces. The original plan was to use Adobe Photoshop to represent the complex relationship between nature and technology. Hundreds of photos of nature and urban areas were taken and formed a neat collection ready for Photoshop. Though I found these images to be interesting, as an artist I was neither challenged nor inspired by the few pieces I created with Photoshop. I found that Photoshop didn't adequately, or to my satisfaction, embody the affinity between nature and technology. In reflecting on past experiences and interests, there is the common theme of nature or traditional forms replaced with technology. In the summer of 2014, I attended an Art Gallery exhibit at SIGGRAPH. SIGGRAPH is an international conference and exhibition on computer graphics and interactive techniques. The installation pieces at the exhibit were made to look like traditional etchings that were framed and hung for display. However, there was nothing traditional about these pieces for they were animated prints that were seamlessly looped on eink. Technology in this instance was used to look at a beautiful traditional art form in a new light. The exhibit inspired me to explore how this could be applied to representing nature and the complex cohesive relationship it has with technology.

II. Nature and Technology

A. Introduction

Both nature and technology are expansive topics. There were many areas that could be explored within both fields. To pinpoint and narrow down the area that I would further

investigate, I started by brainstorming and writing adjectives that defined nature and technology in separate columns. Within each list, there were many contradicting notions. For instance, nature encompasses both life and death; it is very much about cycles and change; evolution. Technology aids people for practical purposes; however, it can also cause frustration and has some negative effects.

B. Technology

Constantly changing, technology is revolutionizing the way people behave and is enhancing what we are able to achieve. Technology has enabled humans to express their individualism in new ways through social media. Using social media and smartphones as tools, individuals are able to create a personification of themselves that is constantly edited. In looking around, human beings are in constant connection with technology. Smartphones have become so ubiquitous that people are uncomfortable moving around without them; they have become an extension of the human body. Smartphones contain easy access to information and extend stored memories in the form of photos. The human body is itself biologically natural with limitations; today's generation is increasingly reliant on technology. In this way, humans' identities are intertwined with technology.

C. Nature

Every human and living being is unique. However, biologically, humans are remarkably similar. There is an average genetic difference of 0.1% between individual people; "DNA or deoxyribonucleic acid, is the molecule that makes up an organism's genome in the nucleus of every cell. It consists of genes, which are the molecular codes for proteins – the building blocks

of our tissues and their functions."[1] With only a 0.1% in variation, it is remarkable how much people vary. In looking at the molecular make up, "all living things are fundamentally alike… these fundamental similarities are most easily explained by evolutionary theory: life shares a common ancestor."[2] Though humans share a common ancestor there is much variation because of evolution.

[1] "Genetic Evidence." The Smithsonian Institution's Human Origins Program. The Smithsonian National Museum of Natural History, n.d. Web. 11 Mar. 2015. <http://humanorigins.si.edu/evidence/genetics>.

[2] "Cellular/Molecular Evidence." *Lines of Evidence: Molecular Evidence*. N.p., n.d. Web. 01 Mar. 2015. <http://evolution.berkeley.edu/evosite/lines/IIDmolecular.shtml>.

Part Two

Inspiration of Evolution Theorist

I. Evolutionist: Darwin and Haeckel

Evolution has been explored by many individuals. "Darwin's theory of evolution by natural selection is one of the best substantiated theories in the history of science, supported by evidence from a wide variety of scientific disciplines, including paleontology, geology, genetics and developmental biology."[3] Darwin influenced and inspired many other individuals, including Ernst Haeckel. Haeckel was a German biologist, naturalist, and artist from the early 1900's, the same time period as Darwin. He was the first full professor of zoology in Jena, Germany and was renowned for his emphatic advocacy of Darwin's theory of evolution.[4] Though Haeckel was a strong supporter of Darwin, he did not believe in Natural Selection; instead, he believed in Lamarckism, which is the belief that the efforts of an individual organism during its lifetime in terms of acquired characteristics can be passed on biologically to its offspring.[5]

II. Haeckel

A. Haeckel as an Evolutionist

From an evolutionary standpoint, his work to many is controversial. According to Paul Dombrowski, Author of *Ernst Haeckel's Controversial Visual Rhetoric*,

> Even after one hundred years, Haeckel sparks controversy. Though lauded in contemporary politics for his contributions to the ecology and environment movements, he is disparaged for his contributions to eugenics and race science. Scholars since the 1960s have linked the Monist League that he formed and its

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[3] Than, By Ker. "What Is Darwin's Theory of Evolution?" LiveScience. TechMedia Network, 07 Dec. 2012. Web. 25 Feb. 2015. <http://www.livescience.com/474-controversy-evolution-works.html>.

[4] p.9 Haeckel, Ernst. Art Forms in Nature: The Prints of Ernst Haeckel. Munich: Prestel, 1998. Print.

[5] "Art Forms of Nature – The Ernst Haeckel Collection." ~ Kuriositas. N.p., n.d. Web. 07 Mar. 2015. <http://www.kuriositas.com/2012/01/art-forms-of-nature-ernst-haeckel.html>.

> amalgamation of science, philosophy, and ethics to later German movements calling for holistic, intuitivistic "science," such as in the volkisch movement, and to still later Nazi pseudo-science (Harrington; Stein; Burke; Gasman).[6]

B. Inspiration: Haeckel as an Artist

Aside from these controversial claims, there is no disputing that Haeckel was an extraordinarily talented artist. Many species were identified and documented by Haeckel. He drew minutely intricate drawings of microscopic organisms and species. To achieve this, he looked with one eye through his microscope while drawing.[7] There is great attention to his drawings and illustrations, which merged the relationship between art and science in those early years. In addition to his work being extremely detailed, Haeckel had a masterful way of laying out his compositions. Haeckel's

> world view – politically as well as naturally – was one of order, organization and symmetry. The subjects of each lithographic plate were carefully selected so that they would encapsulate the organization of organisms – with symmetry of paramount importance. Each image of each plate was carefully arranged to maximize their visual impact and to drive home Haeckel's worldview.[8]

Symmetry is a common sight in Haeckel's work. In addition, one very prominent shape found in Haeckel's prints and thus in nature is starfish like patterns. These figures have an array of characteristic types of tentacles that present a variation in this pattern form. Figure 1-8. This five-sided shape along with symmetry is repeated throughout my thesis sculptures.

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[6] Dombrowski, Paul. "Ernst Haeckel's Controversial Visual Rhetoric." Technical Communication Quarterly 12.3 (2003): 303-19.ProQuest. 1 Mar. 2015.

[7] "Ernst Haeckel - Wall Charts - Acanthophracta." Ernst Haeckel - Wall Charts - Acanthophracta. N.p., n.d. Web. 01 Mar. 2015. <http://legacy.mblwhoilibrary.org/haeckel/wallcharts/acanthophracta.html>.

[8] "Art Forms of Nature – The Ernst Haeckel Collection." ~ Kuriositas.

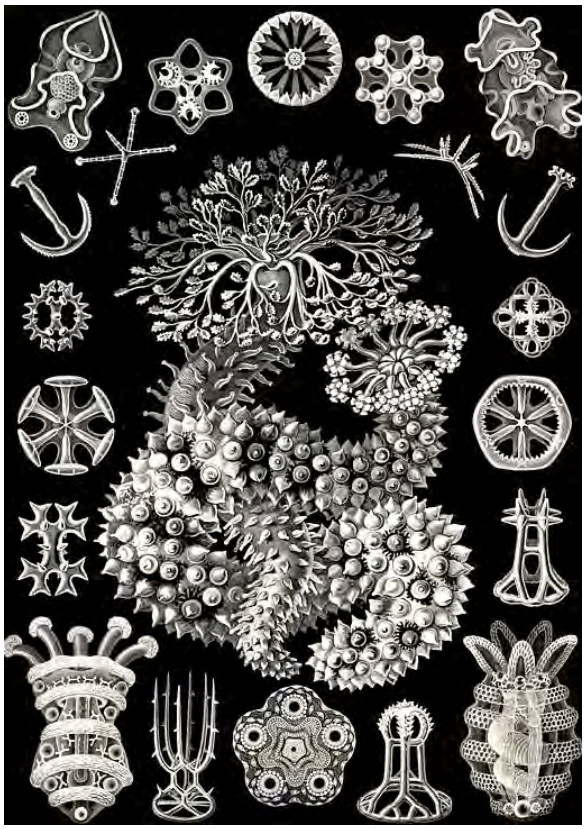

Figure 1 Haeckel, Ernst. 'Thuroidea' Digital

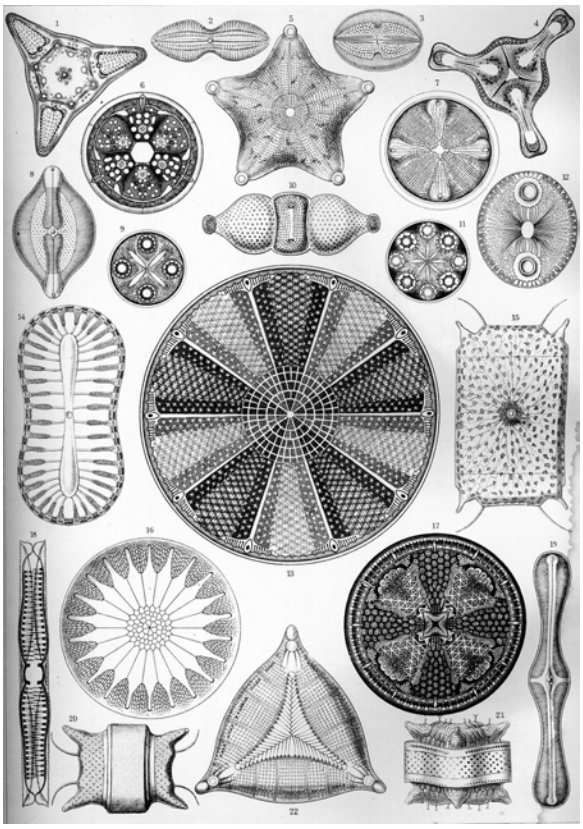

Figure 2 Haeckel, Ernst. Plate 4: Diatomea

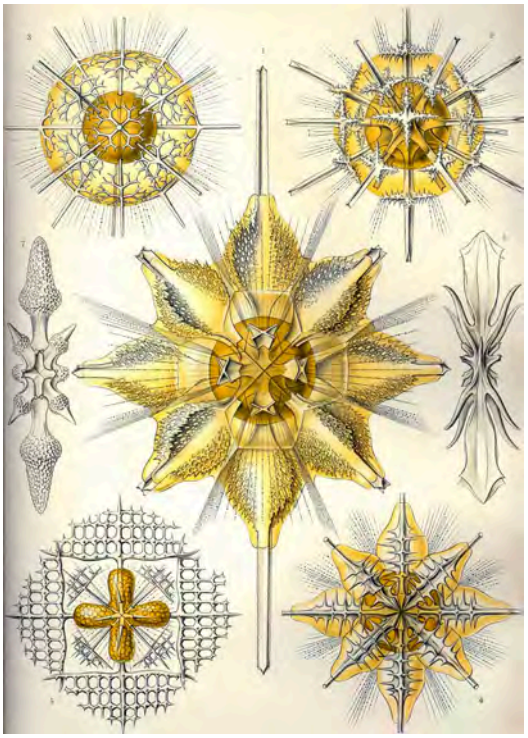

Figure 3 Haeckel, Ernst. Plate 21: Acanthometra

Figure 4 Haeckel, Ernst. Plate 16: Narcomedusae

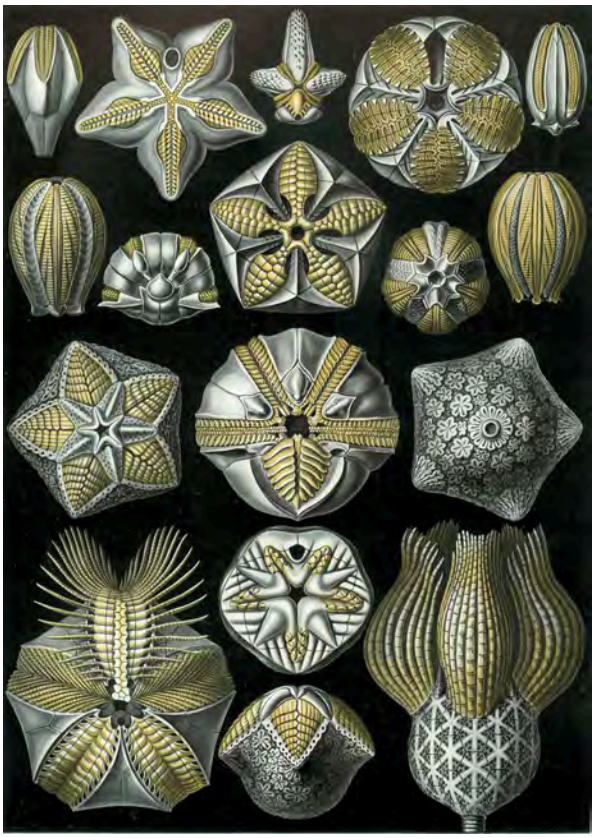

Figure 5 Haeckel, Ernst. Plate 80: Blastoidea

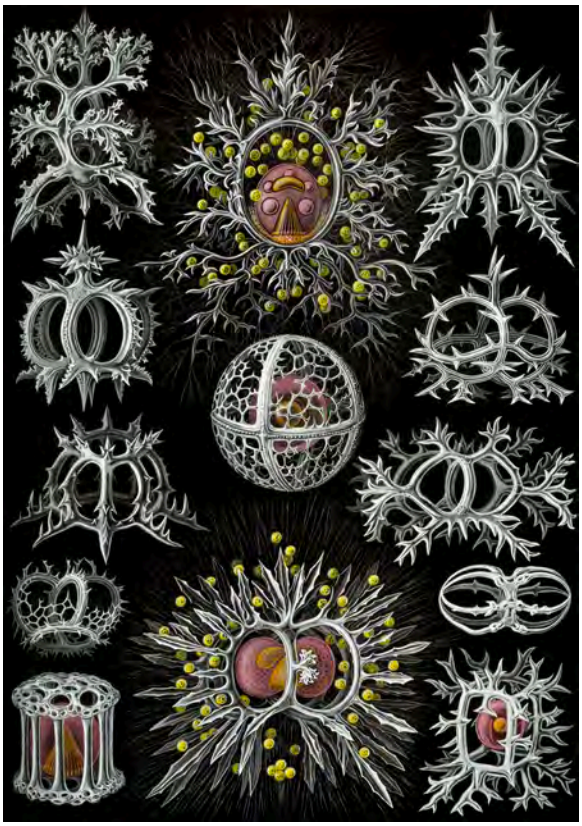

Figure 6 Haeckel, Ernst. Plate 71: Stephoidea

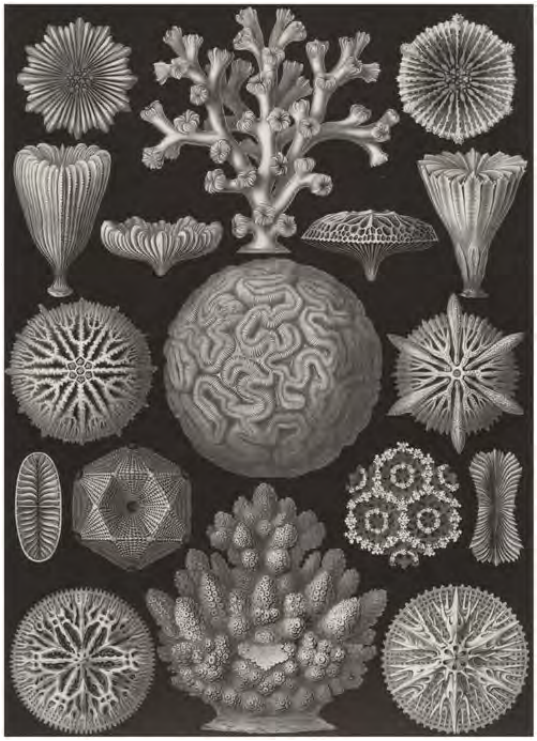

Figure 7 Haeckel, Ernst. Plate 26: Hexacoralla

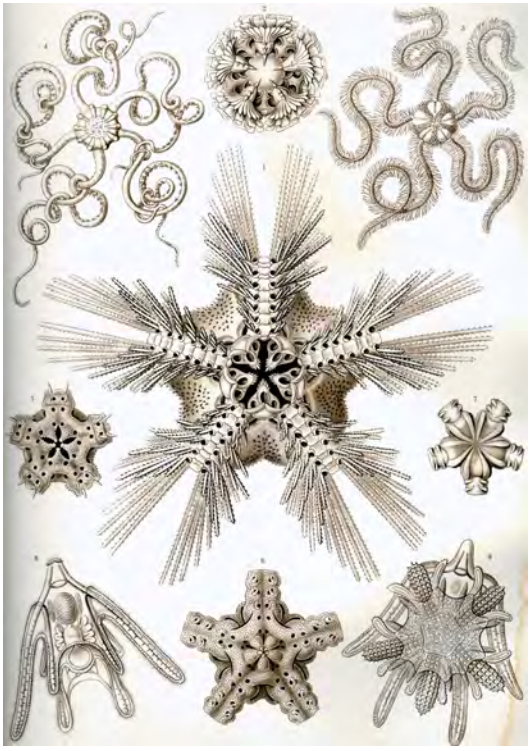

Figure 8 Haeckel, Ernst. Plate 10: Ophiodea

Haeckel believed that "knowledge of nature is 'natural aesthetics.' Accordingly, aesthetics are nothing more than reflections of nature itself, nature which develops out of and into itself is 'beautiful.'"[9] My work was very influenced by these natural symmetrical forms that Haeckel illustrated. When modeling the sculptures, Haeckel's designs and attention to symmetry were in my subconscious mind. While Haeckel drew from observation, I did not; instead each model was my original creation, fashioned through Cinema 4D. Although my models were not based off of legitimate biological molecules found in nature, my models, specifically the internal structures, seamlessly fit into his series. Figure 9. Nature and technology are vastly different, and yet the two coexist. To represent this cohesion between nature and technology, I decided to use an advanced 3D modeling and animation software, Cinema 4D. While bearing Haeckel's designs in mind, I used this software to sculpt molecularly inspired figures.

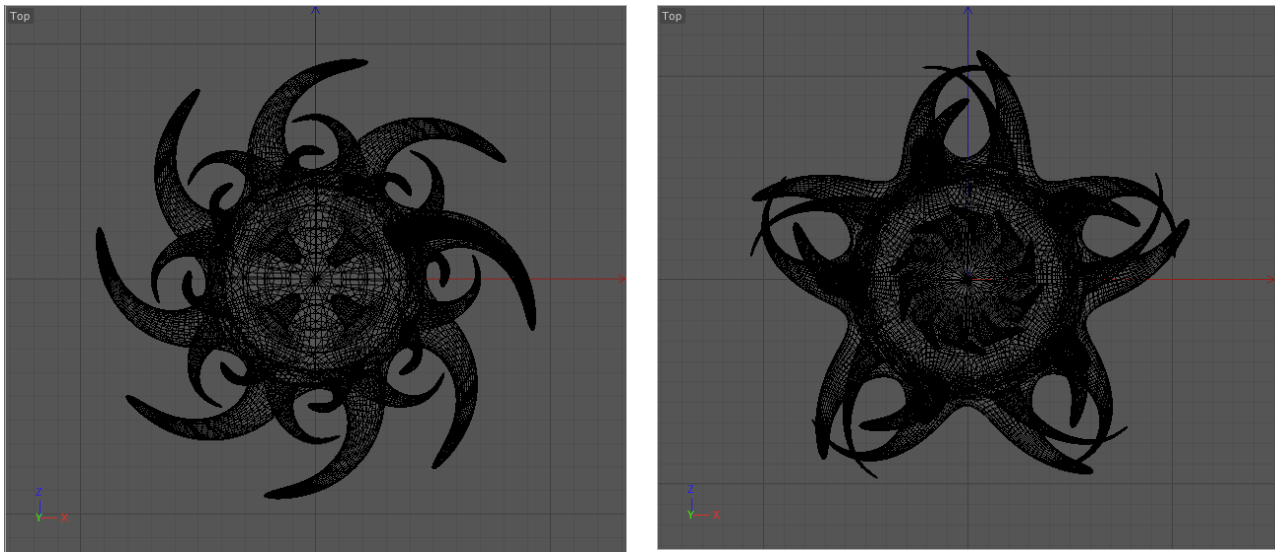

Figure 9 Cinema 4D Bird's-eye view of two final thesis model's mesh structure

[9] p.14 Art Forms of Nature.

Part Three

The Technological Process and Production

I. Introduction

As previously mentioned, technology undergoes changes both radically and quickly. Within the last few years 3D printing has become accessible and affordable to thousands of people. There is a movement to supply 3D printers in schools so young children are familiar with them and will be facile in using them in the workforce once they get there themselves. MakerBot has recently launched Starter Lab, which is an initiative to get schools started with 3D printing; the goal of the program is "to create early education on 3D printing, and get kids started early with creating."[10] By having access to a MakerBot printer myself, I 3D printed the sculptures that were first modeled in Cinema 4D.

II. Cinema 4D and 3D Printing

A. Initial Sculpting and Creating

The sculptures were fashioned in Cinema 4D; each model had to go through a series of steps to become 3D printer-ready. Each sculpture started from a sphere that was subdivided into various segments. Then several of these segments, by choice, were selected and extruded or inverted into different lengths and rotated at different angles. Many of the choices were influenced by Haeckel's symmetry. For instance, Haeckel's Plate 1 from Kunstformen der Natur (Figure 10) is a lithograph of Phaeodria. Phaeodria or Cannopylea form a special main group

[10] Swanner, Nate. "MakerBot Announces Startup Lab for Schools, Businesses." SlashGear. N.p., 4 Mar. 2015. Web. 12 Mar. 2015. <http://www.slashgear.com/makerbot-announces-startup-lab-for-schools-businesses-04372058/>.

(legion) within the subclass of Radiolaria or Strahlinge.[11] My sculpture (Figure 11) reflects a few of Haeckel's spherical figures in Figure 10. It includes both the extruded tentacle forms and the hollowed forms. This is the basic creative part of constructing the sculptures: choosing which parts are extruded or inverted and at what length, etc. At this point the extruded segments are very angular. To make the edges soft and round the object must be dropped into a HyperNurb, also known as a subdivision surface. Once the exterior of the model is considered finished, as Figure 11 is, there are many steps necessary to make the sculpture ready to print.

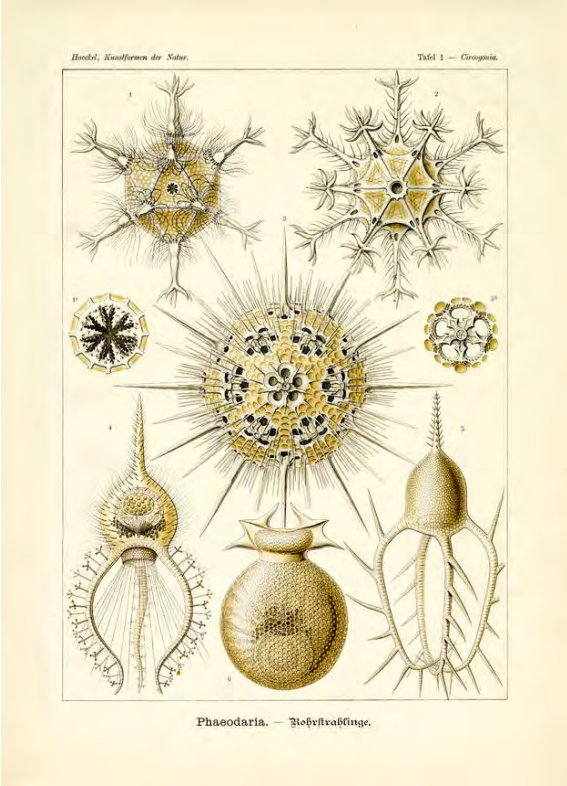

Figure 10 Haeckel, Ernest. Plate 1 Phaeodria

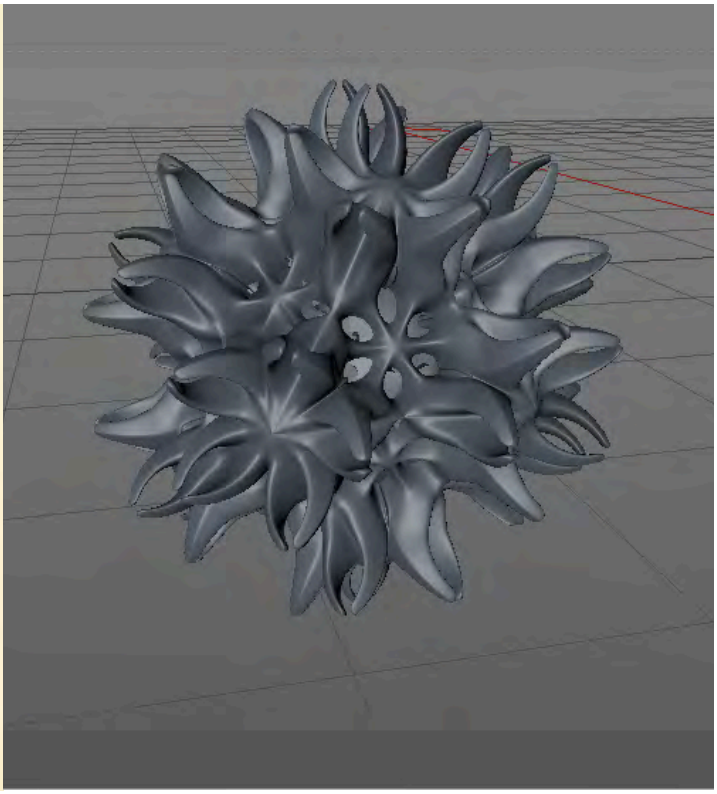

Figure 11 Cinema 4D in progress Thesis Model

[11] "Kunstformen Der Natur." Mediamatic.net - Circogonia. / Phaeodaria. Rohrstrahlinge. N.p., n.d. Web. 12 Mar. 2015. <http://www.mediamatic.net/374447/en/circogonia-phaeodaria-rohrstrahlinge>.

B. 3D Printing Insight

The MakerBot printers use PLA filament, which is a nontoxic resin, made of sugar derived from field corn.[12] The print head is heated to 215° C, which is 419° F, from which point the PLA is extruded onto the print bed. The print head moves laterally across the print bed; the PLA cools and hardens very quickly in the path that has been printed. The printer continues this process, often hours on end, creating hundreds of layers to form the 3D printed object. Therefore objects that have a flat surface print best because they adhere flat to the print bed without support material. If an object that is being printed has an overhang that is less than 45 degrees, then support material is needed. However, if the overhang is more than 45 degrees the printer is able to shoulder enough material on the layer before to not require any support material. Figure 12 demonstrates this as some of the tentacle forms are printed with support structures while others are not.

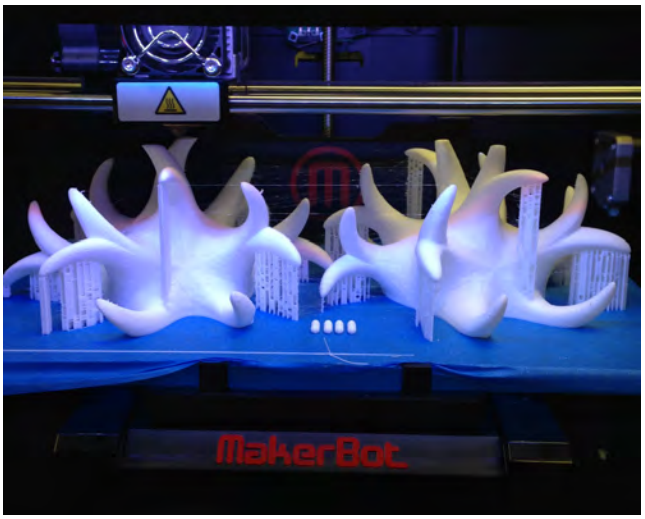

Figure 12 MakerBot Printing with Support Material

[12] "MakerBot PLA Filament." *MakerBot*. N.p., n.d. Web. 1 Mar. 2015.

In addition to being easier for the printer to print flat objects, from a cleaning perspective it is much better to not deal with support material on bottom layers of the print. In order to successfully print the complex and intricately modeled thesis pieces using the MakerBot printer, the models have to be divided into two pieces, with flat bottoms. Additionally, MakerBots use a honeycomb structure on the interior of the prints. This not only conserves PLA but it also makes the structure very strong. The sculptures were designed to have a hollowed sphere in the interior; this saves both time to print and material. Both of these tasks had to be done in Cinema 4D.

C. Making the Models Printer Ready

After the model is initially created, in Cinema 4D, by extruding the various points, the sculpture/object must become editable. To break the entire process down into simpler terms, the models are created out of many shapes in Cinema 4D that then have to be connected and deleted until it is just one object to print with good geometry. The piece can't have any polygon holes or else the MakerBot will not know how to process it. In order to make the object hollow, once the object is editable, a sphere must be subtracted from the sculpted model by booleing it. Booles allow the users to control how objects relate to one another to create complex models from simple shapes.[13] In this instance, since the model started as a sphere, it most closely resembles a sphere for the interior; in retrospect, any shape could have been used to make the interior hollow. Once the sphere is perfectly centered to the modeled piece both objects must become children of a boole, which is set for an A subtract B formula. Those must become editable, then connected and deleted; then the model is hollowed. It is a similar process to halve the hollowed model except that two separate booles are necessary. The hollowed model must get copied and pasted,

[13] McQuilkin, Kent, and Anne Powers. *Cinema 4D: The Artist's Project Sourcebook*. Waltham, MA: Focal, 2011. Print.

so there are two identical models. A large square that encompasses the top half of one of the hollowed models is booled with the model while a second large square that covers the bottom half of the other model is booled with this second hollowed model. This produces the top and bottom halves that are ready to print. This is the basic procedure that goes into preparing the files for printing. In order for the two halves to connect, magnets had to be booled out as well. It would be easier to glue the halves together except that LED lights are incorporated and housed in the hollowed centers. This is another reason the objects were printed in two halves. The LED circuit needed to be installed and in case it needed modifications, it had to be accessible.

D. Incorporating LEDs

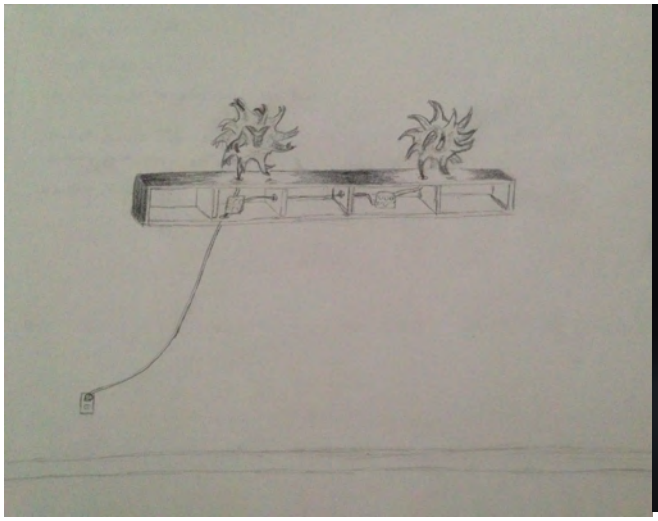

Figure 13 Design Sketch for LED Circuit

Figure 14 LEDs Incorporated

Every living entity, whether it is a plant or animal relies on light and sun. Manmade electricity has aided mankind in more ways than not. To abstractly convey humans' reliance on the natural sun along with electricity, the 3D printed sculptures on display on the floating shelves in the visual arts alcove have LED lights housed within them. The sculptures softly glow (Figure 14). The duration of the exhibition posed a problem. Originally, a small cylinder was booled out

of the interior of the models to hold a small battery run LED candle (1.5 diameter). This was not suitable as a long-term solution as the batteries lasted for only 36 hours. The final show is ten days long. This presented a problem with powering the LED for such an extended time. The final solution is a circuit with all the connecting wires hidden in the floating shelves. Rechargeable multicolored tea lights were rewired and soldered to wall warts. Three extension cords connect to outlets and string up to the floating shelves giving continuous power to the models. Figure 13.

Part Four

The Exhibition

I. The Show Pieces: Evolution

The designs of the twelve glowing models in the alcove visually represent evolution. Haeckel believed "humans are nature, they are a part of, and result of, evolution. Our actions and thoughts are products of this evolution."[14] Some of the models have three different stages of evolution represented, others with two, and then there are single models. However, all models could be related and stem from one simple model. Thus in the alcove there is an abstract lineage at different points of evolution. The additional models are on freestanding pedestals in the gallery. These models do not glow but will incorporate growing vines and plants. Figure 15.

Figure 15 Cinema 4D Render of the Exhibition Layout with the Alcove and Freestanding Pedestals

(Note: the alcove models will glow and the models on the freestanding pedestals will be moss covered)

[14] p.14 Art Forms of Nature.

II. Adding Nature

A. Moss Introduction

To add another level of complexity to the relationship between nature and technology, the 3D models on the pedestals will have moss growing on them. As Haeckel's designs suggested, symmetry is a constant theme in nature. However, within nature there is also irregularity and imperfection. Though it can be flawed, nature takes its course and continues to thrive. It takes time for plants to engulf other objects. Growing a biological form on the symmetrical 3D printed models symbolized the asymmetrical component of nature. Moss is the oldest terrestrial plant on earth and is present on all seven continents.[15] In this way moss embodies the history and change within biology and humanity. With this natural plant growing on a manmade material there is the underlying metaphor of adaptability and survival. Nature and natural beings coexist with technology and synthetic material goods on a daily basis.

B. Growing Moss

Professor Rice of the Biology Department at Union College has spent many years working with moss. I approached him to ask advice about growing moss on the 3D sculpted objects. He suggested I observe and work with him and a student he was advising for a thesis project. Their project encompassed 3D printing moss structures and explored growing moss on those structures. Thus I tagged along in hopes of successfully learning how to grow moss on my 3D printed sculptures. Initial steps to growing moss for my project began by 3D printing mini models using the same PLA material as the final models would use to be printed. Agar was

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[15] "Moss•ol•ogy- a Fictitious but Believable Name for the Study of True, but Unbelievable Moss Facts." Moss and Stone Gardens. N.p., n.d. Web. 09 Mar. 2015. <http://www.mossandstonegardens.com/mossology.php>.

applied on the surface of the 3D printed test prints. Agar is a gelatinous mixture with nutrients. To apply it, it was first heated then piped on, and refrigerated briefly to solidify. Moss was then applied throughout. The moss did not thrive and eventually died. I suspect there was not enough agar on the models and perhaps there wasn't enough moisture. However, the moss on my sample models lasted longer than the moss on Professor Rice's and his student's model.

C. MakerBot and Stratasys 3D Printer materials correlation to Moss

In discussing with Professor Rice, his student conducted an experiment and found that the 3D printed material being used was leaching chemicals into the moss, which did not enable the moss to photosynthesize. The printer used was a Stratasys, which uses different material than MakerBot printers. The Stratasys 3D printer prints by curing resin with UV light. It is a similar concept to the MakerBot of building up layers to create a 3D printed model; however, resin is used instead of PLA. The resins are "jetted as a liquid from sealed cartridges inserted into the machine. Once a layer of material is deposited on to the 'build tray' it is immediately cured by a UV light. The UV light follows the print head and turns each liquid material layer into a solid. The material is immediately ready to be built upon with successive layers."[16] There are benefits to using this material over PLA: it is more precise and the support material is water-soluble. The down side is that the resin is more expensive than PLA. To print with the Stratasys, the material is 33 cents a gram compared to 25 cents a gram with the MakerBot. If the uncured resin touches unprotected skin and is not cleaned immediately, third degree burns have been known to occur. The moss structure for the biology thesis project was 3D printed with the Stratasys, and that is

[16] "Piles of Reasons - Stratasys for a 3D World." New Scientist 207.2777 (2010): 69. Web. 10 Mar. 2015.

the material that was tested. They found that chemicals leach into the moss inhibiting the moss's ability to photosynthesize.

I conducted an experiment with the PLA material to see if the same results occurred. The PLA material that is used for the models that will have moss on them is comprised of 30% recycled wood. The prints with this PLA will not only look more natural but they will hopefully be more conducive for growing moss. To test this, the PLA was crushed into near powder form and evenly distributed into three small petri dishes, about 0.47 grams in each. Then heated agar was added to the three dishes and to three other control dishes. The six dishes were put into the refrigerator so the ager could coagulate. Moss was added to the six samples and watched over the next couple of days. Figure 16. To test the photosynthesis quality, the six dishes were put into the dark for 10 minutes. Then while in the dark a specific machine blasted the plant with high powered light. A reading was then displayed. In comparing and analyzing the results for the PLA moss and the control group there was no significant difference in the moss' photosynthesis ability. This thus proves that the MakerBot material does not leach chemicals into the moss as the Stratasys does. If grown in the proper conditions, the moss should thrive on the 3D printed models. As the PLA does not absorb water it was difficult to grow the moss on the material evenly. Thus as a solution, instead of moss small vines were grown through the three different models.

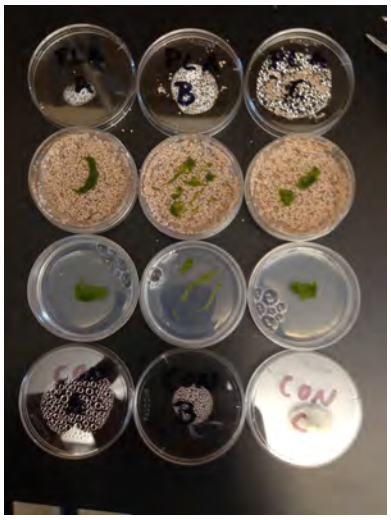

Figure 16

Part Five

Conclusion and Reflection

I. Conclusion

As described, there are many steps that went into producing the 3D printed models for the final exhibition. The showpieces were developed largely with the aid of technology; this differs from Haeckel who drew from observation. By combining art and science, Haeckel opened people's eyes to the beauty and intricacy found in nature. He has been acknowledged for influencing a shift in art in the late 19th century.[17] This shift introduced Art as more modern, moving away from traditional art. During this Art Nouveau movement, "artists drew inspiration from both organic and geometric forms, evolving elegant designs that united flowing, natural forms with more angular contours. The movement was committed to abolishing the traditional hierarchy of the arts, which viewed so-called liberal arts, such as painting and sculpture, as superior to craft-based decorative arts…"[18] A century later, Haeckel's combination of science and nature is still inspiring. The 3D printed sculptures for my final show were inspired by Haeckel and resemble an art nouveau style with elegant and organic forms. 3D printing is not only a technology revolutionizing medicine and engineering science but it is also an emerging art form. The pieces themselves reveal the complex juxtaposition between nature and technology. Without Cinema 4D and 3D printing the sculptures would not have been symmetrically perfect. The symmetrical models themselves are an abstract representation of nature and biology on a molecular level, which drew inspiration from Haeckel's Radiolaria lithographs. The synthetic light that was added to the sculptures accents the reliance of nature on the sun; this also plays

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[17] "Art Forms of Nature – The Ernst Haeckel Collection." ~ Kuriositas.

[18] "Art Nouveau Movement, Artists and Major Works." The Art Story. N.p., n.d. Web. 10 Mar. 2015. <http://www.theartstory.org/movement-art-nouveau.htm>

into how reliant on technology the human species has become, as electricity and light is accessed after dark on a daily basis. By adding vines to the remaining sculptures there is the acknowledgement that every living organism is unique, even within one species. Nature is ever changing and evolving just as technology is. The two entities create a beautiful juxtaposition, for they are so very similar on some levels and differ enormously on others.

II. Reflection

When the time came to start thinking about what I wanted to create for my thesis I knew I wanted to incorporate nature and technology. Human beings are so reliant on both nature and technology. With technological advancements our relationship with nature is constantly evolving. On a larger scale, humans' use of technology is negatively affecting nature. Chemicals from factories are thrown into rivers; non-biodegradable materials, which take years to decompose, sit in landfills leaching their toxins into the soil that could otherwise be used to grow food. These are just a few irresponsible and harmful ways that humans use technology, which is sullying nature. Though slowly, nature does adapt to new environments and conditions. The process of creating the showpieces was very much about adapting. Although 3D printing is a powerful technology, it is still in its early phases. There were many technological problems that had to be resolved. For instance, the extruded PLA filament would not adhere to the print bed on the first layer, causing multiple prints to fail. Fully understanding and delving into the 3D printing technology was not an easy task. These challenges were time consuming and tedious. Throughout the process, I learned that there are multiple solutions to any challenge; it just requires thinking and taking a new approach.

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